Assimilation of aircraft observations in the South China Sea to improve forecasts of tropical cyclones

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1 Introduction of aircraft data for Typhoon Nida (2016)

Figure 1: AIMMS20 was equiped on fixed wing aircraft J41

extrememly inhomogenours distribution

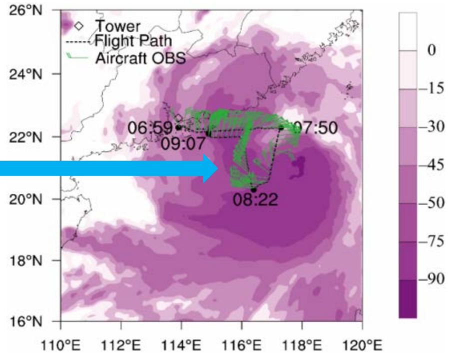

Figure 2: The flight path of aircraft J41 (black dash line) with time stamps (dots), thinned aircraft observations (green wind barbs), and brightness temperature from FY2G (shaded, unit: K) at 0800 UTC on August 1, 2016

Table 1: parameters of AIMMS20

Elements	Range	Accuracy	Resolution
Horizontal wind components (*u* and *v*)	0 to ± 90 m/s	0.5 m/s for straight level flight; 1 m/s otherwise	0.1 m/s
Pressure	500 - 1040 hPa	1 hPa	0.1 hPa
Temperature	-20 - 50 ºC	0.3 ºC	0.1 ºC
Relative humidity	0 – 100 %	3 %	1 %

inappropriate turbulance information for mesoscale model

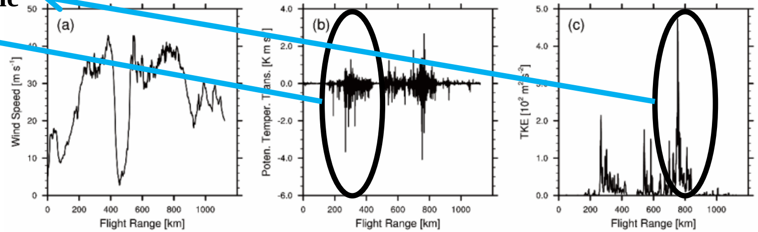

Figure 3: (a) The mean horizontal wind speed (unit: m s^{-1}), (b) the vertical turbulent flux of potential temperature (unit: K m s^{-1}), and (c) the turbulent kinetic energy (unit: 10^2 m^2 s^{-2}) after 30 s moving average

2 Assimilation methods 1: multigrids 3DVAR

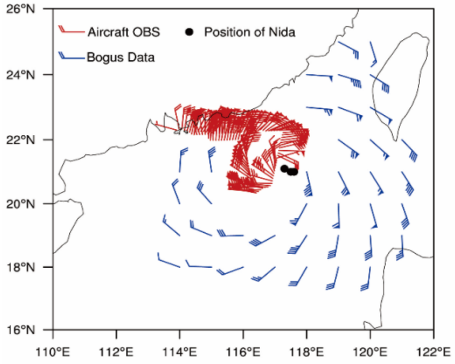

Figure 4: Distributions of thinned aircraft observations (red wind barbs) and bogus data (blue) wind barbs. Black dots represent the positions of Nida during the flight mission

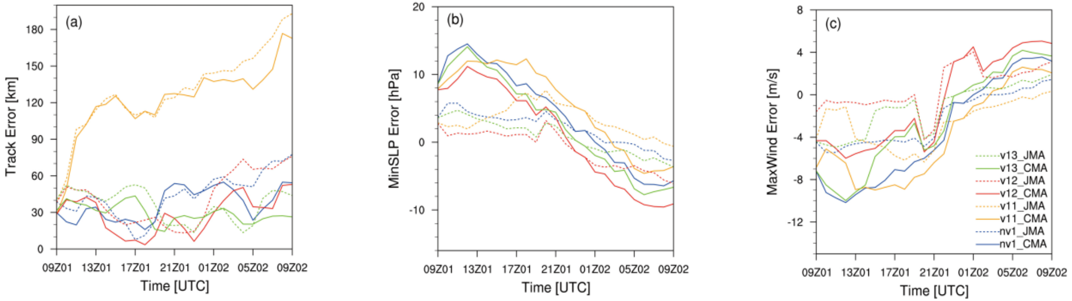

Figure 5: Errors in (a) tracks, (b) minimum sea level pressure, and (c) maximum wind speed computed as the difference between the first set of experiments minus best track from the CMA (solid lines) and JMA (dash lines)

Table 2: Configurations for all the experiments

Exp.	number of grids	grid sizes	radius of recursive filter	observation variables	observation sources
nv1	single	0.09°	null	null	null
v11	double	0.18°, 0.09°	200 km, 100km	wind, pressure	aircraft
v12	double	0.18°, 0.09°	200 km, 100km	wind, pressure	aircraft, bogus
v13	double	0.18°, 0.09°	200 km, 100km	wind, pressure	bogus

→ **Both intensity and track forecasts are improved**

3 Assimilation methods 2: EnKF

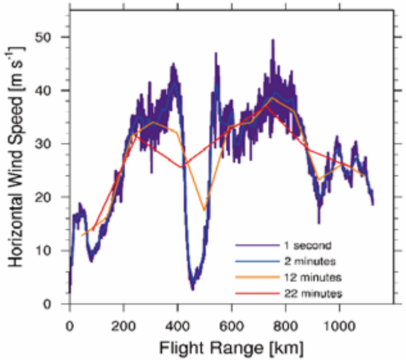

Figure 6: Distributions of horizontal wind speeds (m s^{-1}) along the flight path. The gray line represents raw observations. The purple, blue, orange, and red lines represent the aircraft observations averaged over 1 s, 2 min, 12 min, and 22 min, respectively

Table 3: Summary of experiments

Exp.	Resolutions (temporal/spatial)	reprentation
NE	null	null
E1S	1 sec/0.12 km	subgrid scale
E2M	2 min/14.14 km	grid scale
E12M	12 min/68.47 km	resolvable scale
E22M	22 min/113.13 km	supergrid scale

lager RMSE

the smallest

Table 4: Averaged root mean square errors (RMSEs) of u and v wind, temperature, and pressure compared to raw aircraft observations in all experiments

Exp.	U (m s^{-1})	V (m s^{-1})	T (ºC)	P (hPa)
NE	8.20	8.84	3.10	3.54
E1S	4.36	5.22	3.82	5.95
E2M	3.78	3.74	2.78	2.45
E12M	4.89	4.32	2.96	2.60
E22M	6.35	6.27	3.06	2.84

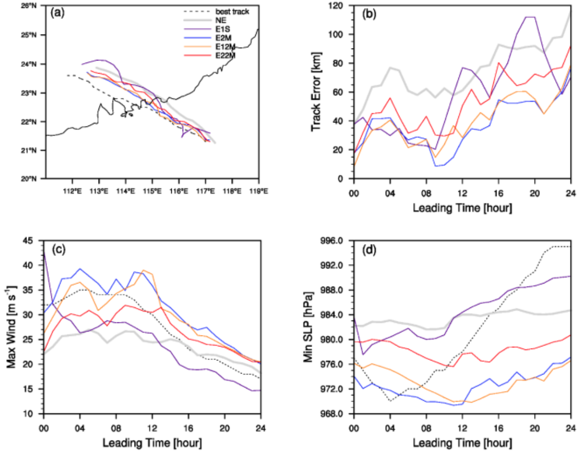

Figure 7: (a) Track forecasts, (b) errors in track forecasts, (c) maximum surface winds, and (d) minimum sea level pressures for Typhoon Nida in the control experiment and data assimilation experiments

4 Conclusions

Aircraft observations in the South China Sea can give forecasts and understandings of TCs several significant benefits:

- High frequency aircraft observations are supplymentary measurements of Typhoon Nida (2016), but they have an extremely inhomogenous distribution and high serial correlations that bring challenges in data assimilation no matter what methods we used.

- Not only the track forecast but also the intensity forecast of Nida is improved only when the bogus data are assimilated with aircraft observations.

- Superior track and intensity forecasts compared to other data assimilation experiments are obtained because aircraft observations thinned at the grid scale enhance the representation of inner core structures of Typhoon Nida.

References:

Gao, Y, Xiao, H, Chan, PW, et al. Application of the multigrid 3D variation method to a combination of aircraft observations and bogus data for Typhoon Nida (2016). Meteorol Appl. 2019; 26: 312– 323. https://doi.org/10.1002/met.1764.

Gao, Y., Xiao, H., Jiang, D., et al. Impacts of Thinning Aircraft Observations on Data Assimilation and Its Prediction during Typhoon Nida (2016). Atmosphere 2019, 10, 754. https://doi.org/10.3390/atmos10120754.